PG&E Battery Energy Storage Pilot Projects

Safety Plans and Lessons Learned

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Jon Eric Thalman
Director Regulatory Strategy &
Transmission Asset Management

Presentation Agenda

- Operational history
- Discussion of battery fire in Japan and impact on project
- Response to fire and ensuing safety enhancements
- Lessons learned

PG&E's Battery Energy Storage Pilots

Vaca-Dixon (VD) BESS
2 MW / 14 MWh NAS Battery
Vaca-Dixon Substation

Operational Date: August, 2012
Commenced testing in CAISO markets: Sep 2013
Completed PG&E's new storage interconnection process: July 2014
Commenced daily market operations: Aug 2014

Current Uses:
- Currently dedicated to CAISO wholesale market participation.
- Project is focused on optimizing for and quantifying revenues from participation in CAISO energy and ancillary services markets.

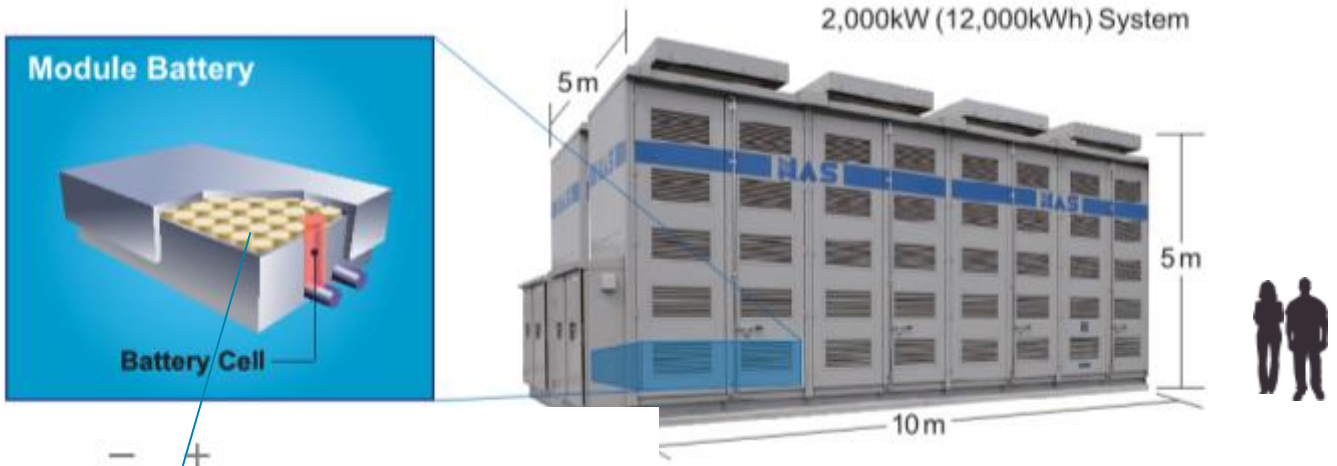
PG&E's Battery Energy Storage Pilots

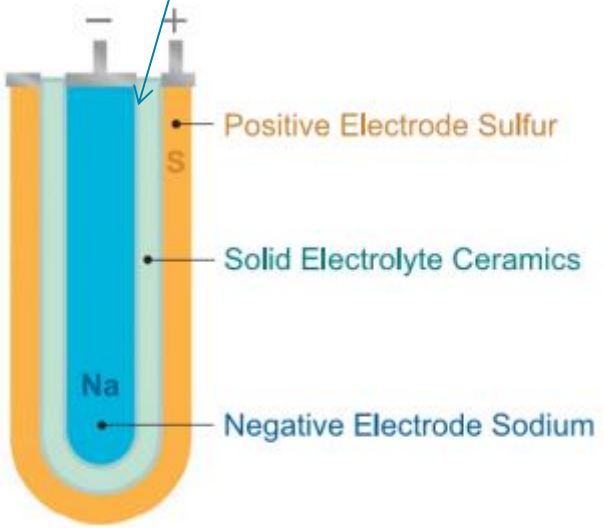
Yerba Buena (YB) BESS
4 MW / 28 MWh NAS Battery
Customer R&D Facility, San Jose

Operational Date: May, 2013
Completed islanding commissioning: Sep 2013
Completed PG&E's new storage interconnection process: Aug 2014

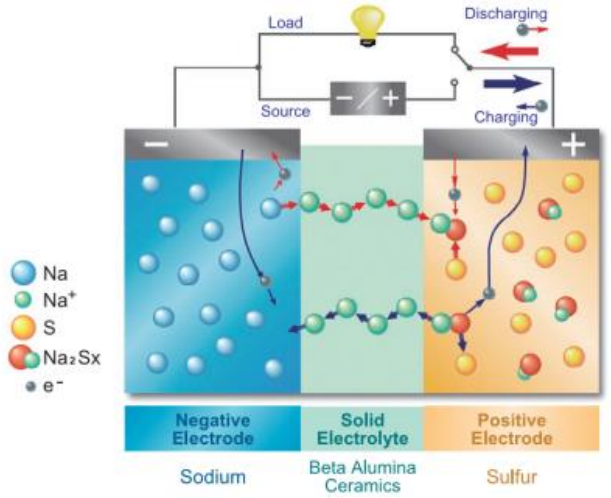
Current Uses:
- Daily peak shaving, with half energy reserved for islanding/backup for the adjacent customer facility.
- Plan to test market participation in Fall, 2015.

Sodium Sulfur Technology





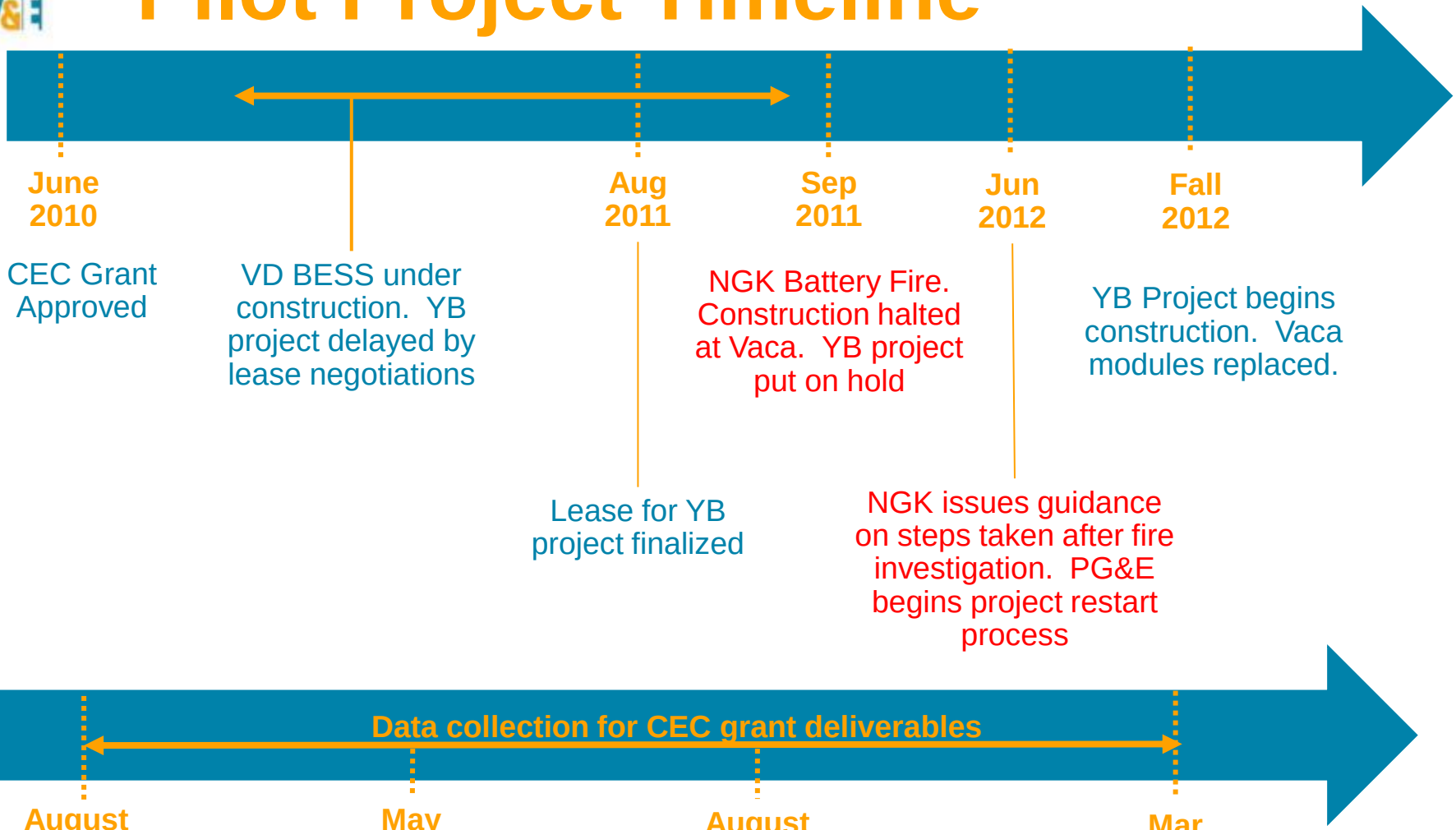
Individual NaS cell



Normal operating temperature for battery is 300ºC.

Sodium and sulfur in liquid form

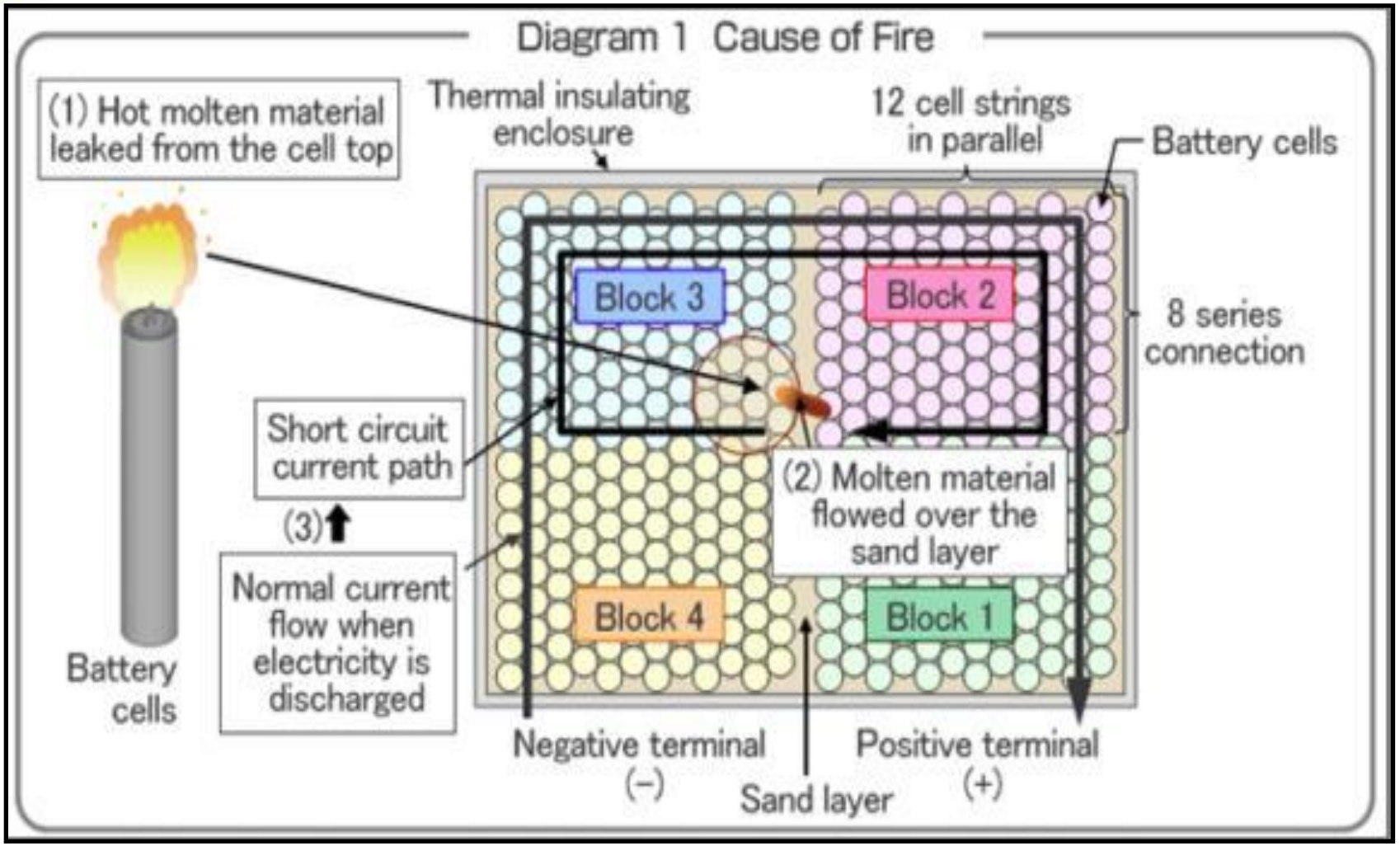
Pilot Project Timeline



Key Causes of Fire

- Molten material from a faulty cell leaked and caused a short between battery cells in an adjoining block.
- Due to lack of sufficient fuses the resulting heat, from the short-circuit, caused a number of other battery cells to catch on fire. This fire spread to the whole battery module.
- The combustion of the particular battery module released flames and hot molten material that melted battery cell casings inside battery modules, which caused the fire to spread further.
- Sodium battery fires (like lithium-ion battery fires) are difficult to extinguish because water cannot be used. The primary mitigation measures are shut down the battery to stop electric flow into the fault and to let the fire burn itself out.

Cause of Fire (ctd)

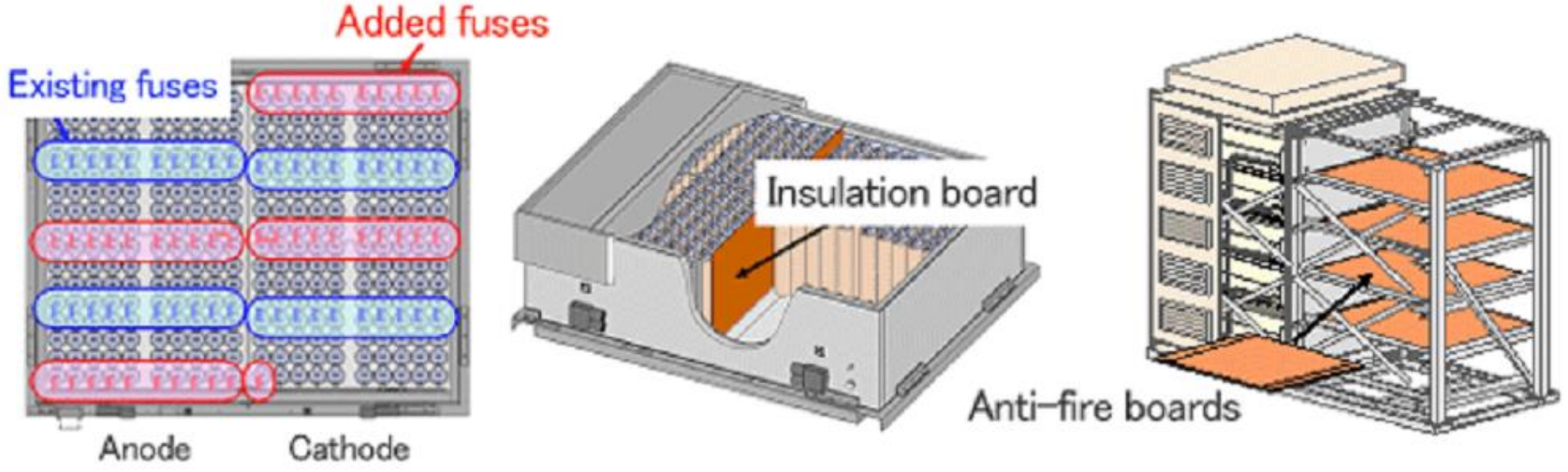


Source: NGK

NGK's Mitigation Measures

- Fuses were added between individual batteries in each module to prevent a short-circuit current from causing a fire.
- Insulation boards were placed between blocks in each battery module to prevent leaking molten materials from causing a short circuit.
- Anti-fire boards were placed between battery modules above and below to prevent fire from spreading to other battery modules.
- Monitoring system put in place to enable quick fire detection

Diagram 2 Fire Containment



Impact to Projects

- New redesigned modules delivered to PG&E in August 2012. Old modules removed and returned to NGK. Overall, project delayed approximately 11 months
- NGK conducted additional testing on new modules (purposely causing cells to catch on fire) and determined fires self-extinguished in 6 minutes or less. Also studied how SO2 dispersed during a fire to fine tune detection system.
- NGK provided PG&E with fire safety plan. PG&E team worked closely with NGK to expand/customize plan for the two installations. This work involved multiple training sessions with substation and fire department personnel
- Safety plan development at Yerba Buena installation accounts for presence of customer facility located close to the battery. Project team worked extensively with HGST personnel to develop joint safety plan.

Key Elements of Safety Plan

- Enhanced alarm system developed and deployed at battery site
- Sulfur dioxide sensors mounted near battery to detect SO2 (byproduct of a fire).
- Personal SO2 monitors supplied for first responders
- Safety perimeter established around battery to restrict personnel entry in event of fire
- Special sand and sand sprayer provided by NGK to cover modules in event of fire (applied after fire self-extinguishes)

Lessons Learned

- Battery technologies (whether NAS, lithium, or others) all have unique safety risks that much be carefully evaluated
- Battery systems must incorporate robust safety detection equipment, technologies, and automated response that can mitigate impacts of an incident such as a fire
- Time and cost of development and deployment of safety plans, mitigation measures, and safety training for internal and external personnel should be incorporated into project timeline and budget
- Important that technology provider have sufficient financial and engineering resources, or be backed by a third party with sufficient resources, to investigate safety incidents and develop and deploy mitigation measures to other deployed systems

Ongoing Safety-Related Maintenance

- 24/7 monitoring by distribution operations with key alerts for fire and SO2 alarms
- 24/7 monitoring by system integrator (S&C Electric)
- Yearly system inspections
- Twice-yearly testing of fire alarm and external SO2 detection systems
- Bi-annual replacement of internal SO2 detector (inside battery modules)
- Ongoing review of battery performance and temperatures to identify potential problems early

Excerpt from Yerba Buena Safety Plan

SAFETY ZONES

In the event of SO2 detection, no one should enter the safety zone without proper PPE and a portable SO2 detector!

RED ZONE:
160 foot perimeter advised for PG&E personnel following guidance from NGK Insulators.

YELLOW ZONE:
330 foot perimeter advised by the Emergency Response Guidebook* and CAMEO** for an SO_2 spill or leak.

*Emergency Response Guidebook (ERG): http://www.phmsa.dot.gov/hazmat/library/erg
**Computer-Aided Management of Emergency Operations (CAMEO) http://www.epa.gov/oem/content/cameo/

Summary

- All battery technologies pose unique safety risks that must be carefully evaluated
- These risks can be substantially mitigated via system design, detection technologies, sound safety planning, and thorough training of responders
- The number of safety incidents have been very few relative to the number of systems deployed.
- NGK's response to its fire incident was very thorough and the company has been extremely forthcoming with information and very engaged partners in developing new safety plans. Its deployment of redesigned modules to all of its systems worldwide (~400 MW) demonstrates a strong commitment to safety.